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AMPLITUDE SCINTILLATION AT 2 AND 30 GHz
ON EARTH SPACE PATHS

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16. Abstract Extensive amplitude scintillation measurements have been made simultaneously at 2.075 and 30 GHz on earth-space propagation paths. These measurements were performed as the Applications Technology Satellite (ATS-6) was moved slowly from a synchronous position over India to a new synchronous position over the United States. The variance, path loss, covariance, and spectra are discussed as functions of the path elevation angle. These results are also compared with earlier simultaneous scintillation measurements at 20 and 30 GHz during the movement of ATS-6 to its position over India [1,2]. This report contains the text of a paper to be presented at the URSI Commission F Open Symposium on Propagation in Non-ionized Media at LaBaule, France, April 28-May 6, 1977.			
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AMPLITUDE SCINTILLATION AT 2 AND 30 GHz ON EARTH SPACE PATHS*

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SUMMARY

Extensive amplitude scintillation measurements have been made simultaneously at 2.075 and 30 GHz on earth-space propagation paths. These measurements were performed as the Applications Technology Satellite (ATS-6) was moved slowly from a synchronous position over India to a new synchronous position over the United States. The variance, path loss, covariance, and spectra are discussed as functions of the path elevation angle. These results are also compared with earlier simultaneous scintillation measurements at 20 and 30 GHz during the movement of ATS-6 to its position over India [1,2].

1 - INTRODUCTION

The movement of ATS-6 from a synchronous position over India to a new synchronous position over the United States was such that the change in the elevation angle of the propagation path was less than one degree per day. Thus, a unique opportunity was presented to measure scintillation characteristics as a function of elevation angle. Phase-locked receivers were implemented at Columbus, Ohio, U.S.A. to receive the 2.075 and 30 GHz ATS-6 beacon signals. 4.6 and 9.1 m Cassegrainian type horn fed parabolic reflector antennas were used. The measured system margins were 48 and 55 dB, respectively. The received signals were digitally recorded at a rate of 10 samples per second at all times during the experiment and at a rate of 200 samples per second on demand; all of the data presented in this paper were derived from the 10 sample per second recordings.

Thirty hours of simultaneous two frequency data were collected between August 29 and October 25, 1976; these data correspond to elevation angles ranging from -0.7° to 43.9° (not corrected for refraction). Samples of these raw data are shown in Figures 1, 2 and 3 for elevation angles of 0.38° , 2.82° and 22.34° , respectively; in these Figures the 2.075 and 30 GHz signals are shown with respect to the mean over the 30 minute data period presented. At the lower elevation angle the peak-to-peak scintillation exceeded 7 dB at 2.075 GHz and 20 dB at 30 GHz. These peak-to-peak scintillation values decreased with increasing elevation angle except that enhanced scintillations were often observed during the presence of non-precipitating cumulus clouds along the propagation path. Although the character of the scintillation appears to change as the elevation angle increases, examination of the spectra of these signals, presented later in this paper, do not show significant differences other than the general reduction of all frequency components. These scintillations were found to occur at all times during the experiment regardless of prevailing atmospheric conditions. All of the data presented in this paper correspond to times when there was no discernible precipitation on the propagation path.

*The work reported in this paper was supported in part by Contract NAS5-25575 between National Aeronautics and Space Administration and The Ohio State University Research Foundation.

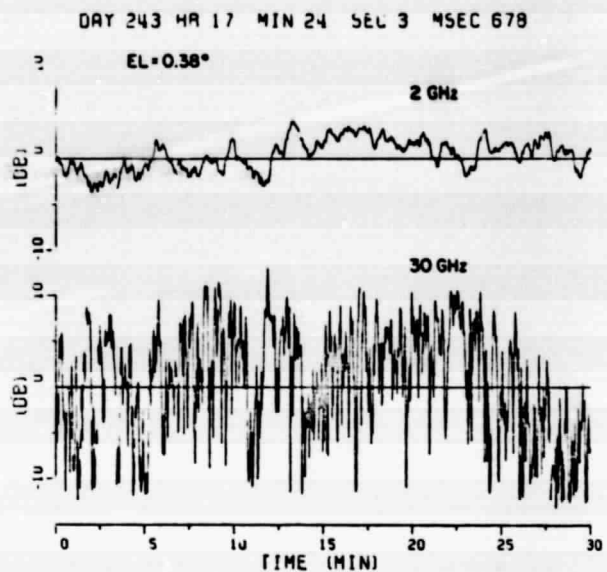


Figure 1. Received signal on day 243.

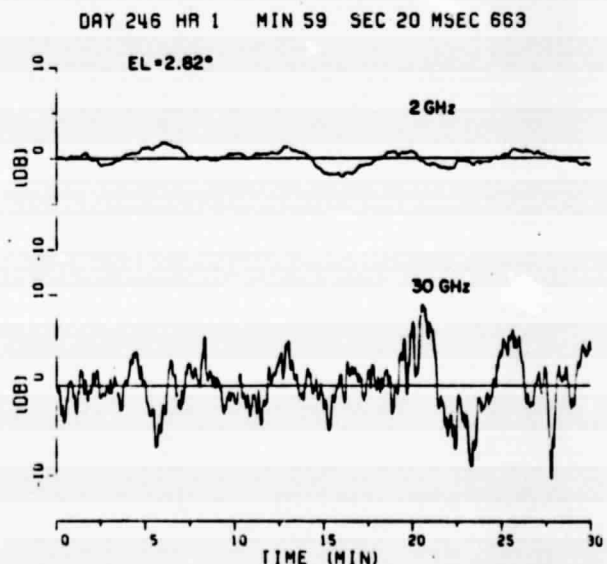


Figure 2. Received signal on day 246.

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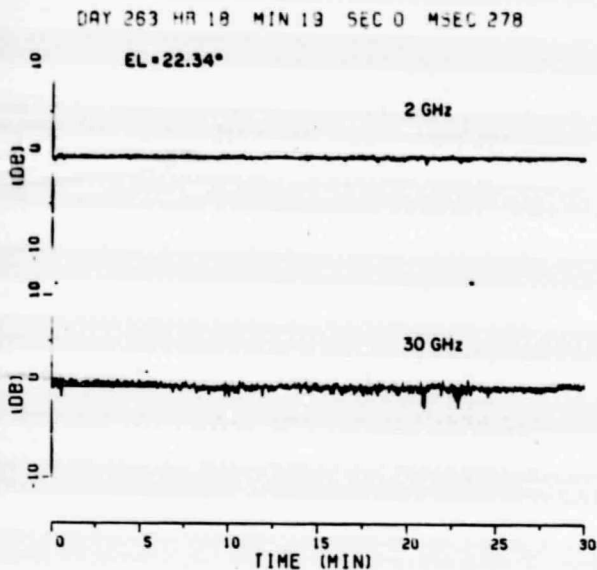


Figure 3. Received signal on day 263.

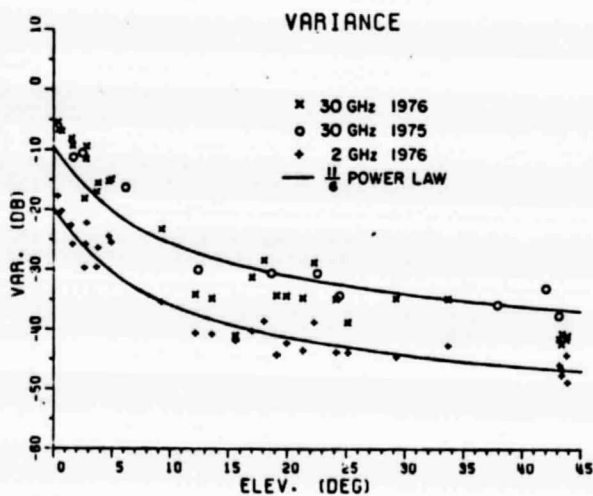


Figure 4. Variance of received signal amplitude.

The variances of these signals have been averaged over each data period and are shown in Figure 4 as functions of elevation angle. These variances were defined as

$$\sigma^2 = 10 \log_{10} \frac{\sum_{i=1}^N (V_i - \bar{V})^2}{N \bar{V}^2} \quad (1)$$

where the V_i are the samples of the received signal amplitude corrected for receiver nonlinearities and $\bar{V}$ is the average over the N samples. The variances were calculated for data intervals of 3.4 minutes, and these variances were then averaged over each data period of 30 to 60 minutes. The spread of the variance over such a data period was often as high as 10 dB. The variance defined in this manner represents the ratio of the power contained in the non-zero frequency components to the power contained in the zero frequency component of the signal. Also shown in Figure 4 are the 30 GHz variance data derived from the earlier set of measurements; these agree well with the current measurements. Theoretical curves have been included to demonstrate the variance behavior under the assumption that the variance is proportional to the $11/6$ power of the path length through a 9 km spherical, homogeneous atmosphere. It can be noted that the measured variance agrees well with this model.

A plot of the variance of the log amplitude of the received signal is shown for comparison in Figure 5. Here the variance of the log amplitude is defined by

$$\sigma_{\log}^2 = \frac{1}{N} \sum_{i=1}^N (V_{\log i} - \bar{V}_{\log})^2 \quad (2)$$

$$\text{where } V_{\log i} = 20 \log_{10} V_i; \quad (3)$$

the subsequent processing was identical to that described above. It is interesting to note that the variance in log amplitude reveals a rather abrupt reduction in level for elevation angles above 6° that is not found in the variance of the amplitude presented earlier. This difference can lead to substantially different interpretations of the same data depending only on the method of data processing chosen.

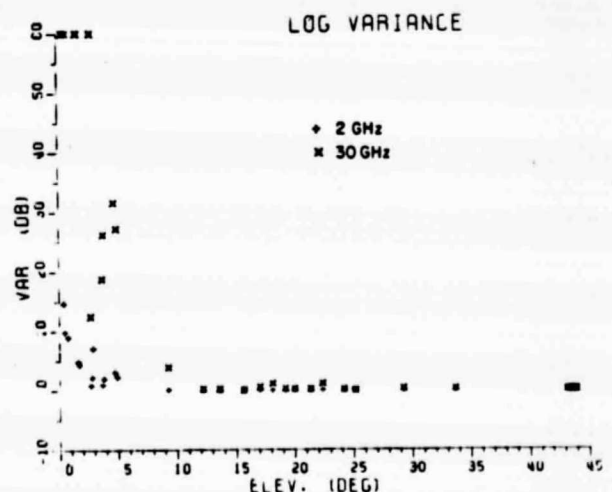


Figure 5. Variance of log amplitude.

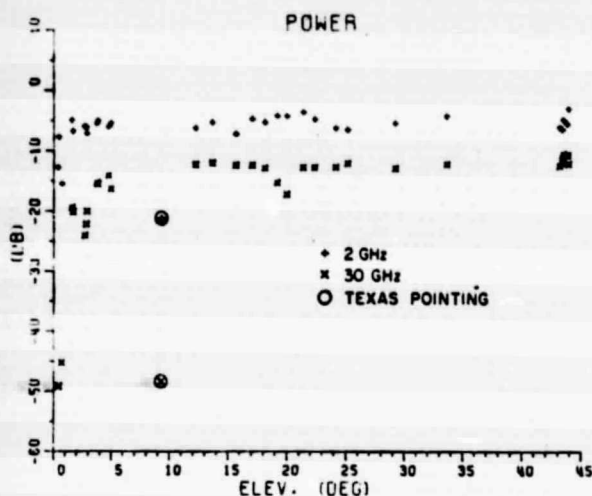


Figure 6. Average power in zero frequency component.

The average power contained in the zero frequency component of the received signal is plotted as a function of elevation angle in Figure 6; the reference in this figure is arbitrary. The dramatic reduction in level at an elevation of 9.3° is due to the fact that the spacecraft antennas were directed toward Texas rather than Ohio during this data period. A substantial reduction in the received power level below that predicted by simple atmospheric path loss calculations at lower elevation angles is also noted; this behavior has been observed earlier by McCormick and Maynard [3].

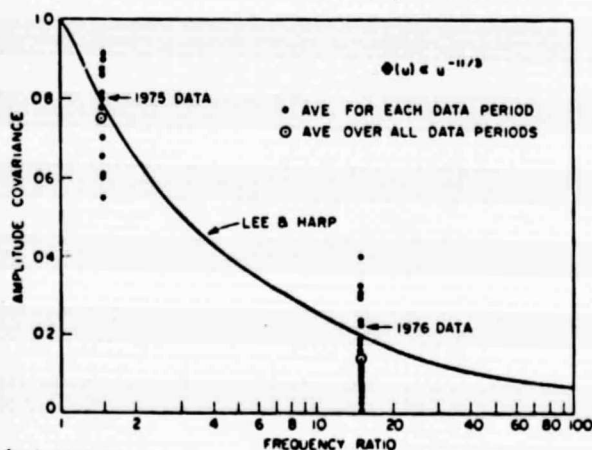


Figure 7. Covariance versus frequency ratio.

The covariance between the 2.075 and 30 GHz signals is shown in Figure 7 along with that for the 20 and 30 GHz data measured earlier [2] and the theoretical covariance predicted by Lee and Harp [4]. Although the spread of the covariance is large, the average over the entire data base agrees well with the theoretical prediction. The covariance is shown in Figure 8 as a function of elevation angle; here it is noted that the covariance decreases as the elevation angle increases. Both the covariance of the amplitudes and the covariance of the log amplitudes are shown in this figure for comparison; though some divergence is found at the lowest elevation angles they are found to agree well at higher elevation angles.

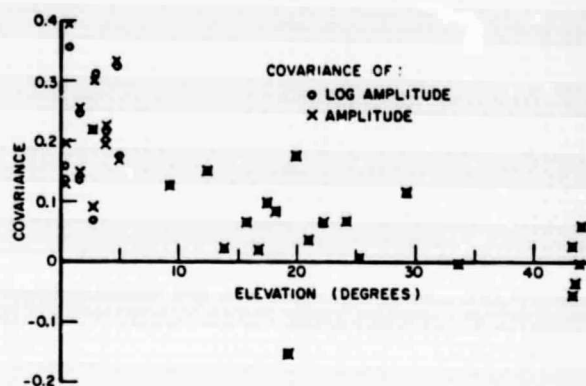


Figure 8. Covariance versus elevation angle.

Spectra of the received signals are shown in Figures 9, 10 and 11; these correspond to 3.4 minute intervals from the data periods shown in Figures 1, 2 and 3, respectively. These spectra all show a characteristic decay with frequency in the range from approximately 0.1 to 1.0 Hz. The spectra tend to be relatively flat for frequencies above and below that range.

Additional processing of these data is in progress and will be reported in a future publication.

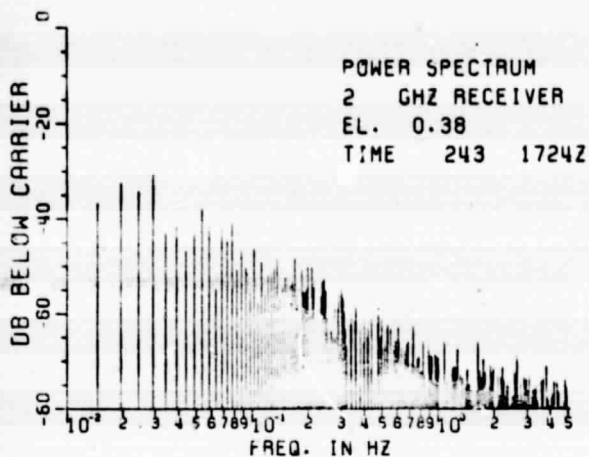


Figure 9a. Power spectrum - day 243.

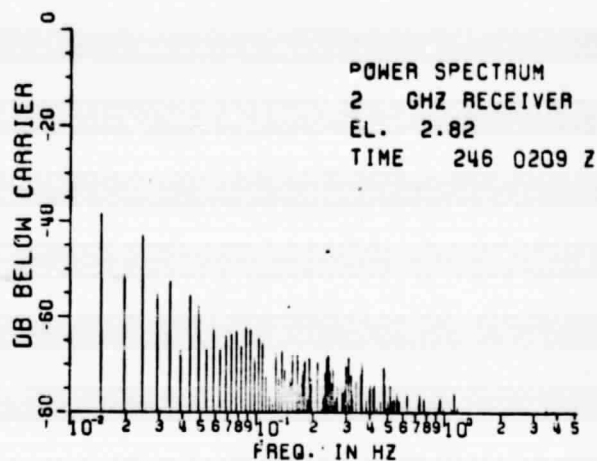


Figure 10a. Power spectrum - day 246.

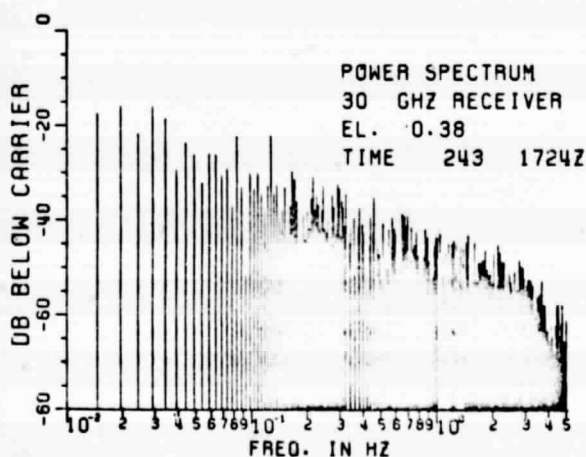


Figure 9b. Power spectrum - day 243.

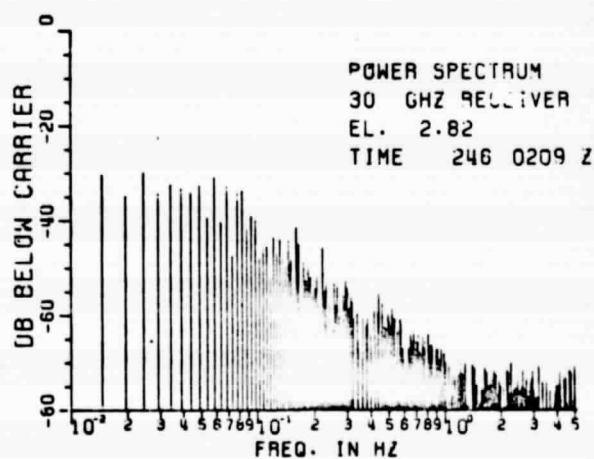


Figure 10b. Power spectrum - day 246.

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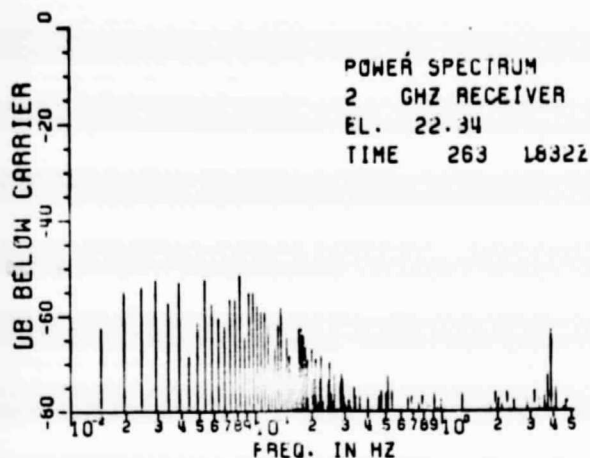


Figure 11a. Power spectrum - day 263.

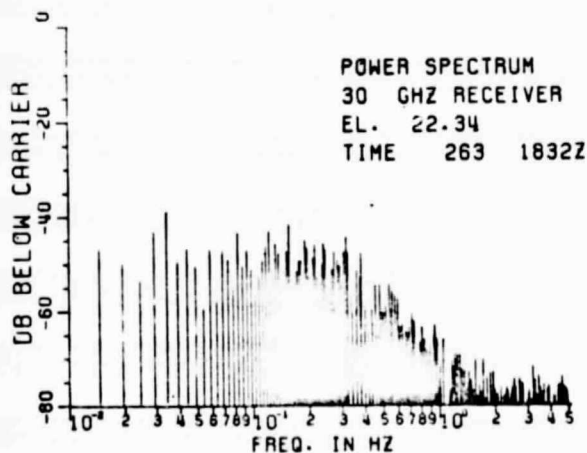


Figure 11b. Power spectrum - day 263.

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